Available online at www.sciencedirect.com

ScienceDirect

Procedia Social and Behavioral Sciences 20 (2011) 263–272

Procedia
Social and Behavioral Sciences

14th EWGT & 26th MEC & 1st RH

Calibration of a micro simulation program for a Chinese city

Li Jie[a,b], Zheng Fangfang[b,d], Henk van Zuylen[b,a,c,*],Lu Shoufeng[c]

[a]*Hunan University, Changsha, PR China*
[b] *Delft University of Technology, Delft, The Netherland*
[c]*Changsha University of Science and Technology, Changsha, PR China*
[d]*South West Jiaotong University, Chengdu, P.R. China*

Abstract

Micro simulation programs are often used to assess the quality of traffic conditions. They are especially suited to evaluate possible control scenarios in advance, so that the scenarios can be selected and optimized before implementation. Of course, the simulation programs should be valid for the traffic situation that has to be modeled with respect to the relevant traffic characteristics. Calibration is needed if there are traffic conditions or traffic behaviors that are different from the situation for which the programs have been calibrated before.

In China the driver behavior is significantly different from Europe or USA. Calibration of microscopic simulation models that have been developed in Western countries is essential for a valid modeling study. This paper describes which traffic characteristics should be used for the calibration of parameters for VISSIM, e.g. saturation flow rates distributions, dependence of saturation flow rates on intersection characteristics, link speed distributions, and speed – acceleration patterns. Not all relevant output from simulations can be used for calibration, because simulation programs have limitations in the traffic characteristics they can reproduce.

Keywords: Simulation, calibration, driver behavior, VISSIM, China

1. Introduction

Micro simulation programs are often used to analyze traffic situations, to assess the quality of traffic control and to evaluate alternative traffic measures. If different traffic management measures are compared using a simulation program, the best one can be chosen and further optimized, using the performance of the simulated traffic as evaluation criterion, e.g. the total time spend, the total length of queues, the number of completed trips per time interval etc. (Dowling et al. 2004, Toledo et al. 2003, Park and Qi 2005)).

The validity of the conclusions that can be drawn from such simulation studies strongly depends on the validity of the simulation. If the validity of the simulation programs is not sure, the risk exists that the traffic engineer

* Corresponding author. Tel.: +31626158161; fax: +31135056332.
E-mail address: h.j.vanzuylen@tudelft.nl.

1877–0428 © 2011 Published by Elsevier Ltd. Selection and/or peer-review under responsibility of the Organizing Committee
doi:10.1016/j.sbspro.2011.08.032

chooses traffic management measures that perform well in the simulation, but are not appropriate for the real situation.

For the simulation programs developed in the USA or in a European country, it is especially an important issue when they are applied in countries with a completely different traffic pattern. As Fellendorf and Vortisch (2001) show, even between freeway traffic in Germany and in the USA there are differences that make a calibration of simulation parameters necessary. One reason is that the traffic composition in Asian countries differs from that in Western countries. A more important cause is the different driving behaviour with respect to reacting to signals, car following and lane changing. Cultural differences make it necessary to adapt simulation programs to represent real traffic in such countries. The adoption of the default parameters of a simulation program is only warranted if these values apply to the local situation. This is certainly not the case if a simulation program, developed, calibrated and validated in a Western country, is applied in a Chinese city with quite different driving behaviours, using the same simulation parameters.

For Changsha, the capital of Hunan Province in China, a simulation model with the VISSIM program has been set up for a study area in the centre of the city. The distributions of saturation flow rates and travel time over links and corridors have been measured and also lane changing has been directly observed on the road sections close to the intersections. The saturation flow rates in Changsha appear to be different from the ones measured in The Netherlands and also lower than the values calculated according to the HCM method (Li et al, 2009, 2010). Furthermore, compared with Western countries, lane changing is often done in a more aggressive way in Changsha where the leading mechanism is 'gap creation' rather than the gap acceptance. Car following is also different in the sense that drivers accelerate more slowly and keep a longer headway, furthermore leading to a lower saturation flow. At the same time, the variation between drivers is also much larger than what is observed in Western countries.

Using observations from probe vehicles (6000 taxis with GPS), video observations and loop detector data from the SCATS network traffic control system, the characteristics of the vehicle traffic was captured. This is used to adapt the relevant parameters of VISSIM to match as well as possible with the observed traffic behaviour.

This article describes first the importance of saturation flow rates and its variation for calibration. The second section deals with travel time distributions. It is well known that travel time in urban networks is rather uncertain due to stochastic character of queues and the stochastic effect of traffic control. Section three explains the characteristics of the measured saturation flow in Chnagsha and the calibration of simulation parameters to obtain a valid saturation flow. Section four discusses the way how vehicle trajectories can be used to calibrate free speed and acceleration / deceleration distributions.

2. Travel time distribution

Further calibration can be done to reproduce the link travel time distributions. For the Changsha network, the travel times are derived from probe vehicles provided with GPS and GPRS. Every 30 seconds the positions of 6000 taxis are sent to a central computer. The stored data have been analyzed to get the link travel time distributions. First of all, trips on single links in the network were selected. The outliers are identified as vehicles that disappear from the region around the link for more than 90 seconds. In fact this is a relative large proportion of the vehicles because many taxis often leave the arteries and take their routes over minor streets.

The distribution of travel times has been validated by matching the distribution pattern to an analytical function developed by Zheng and van Zuylen (2011).

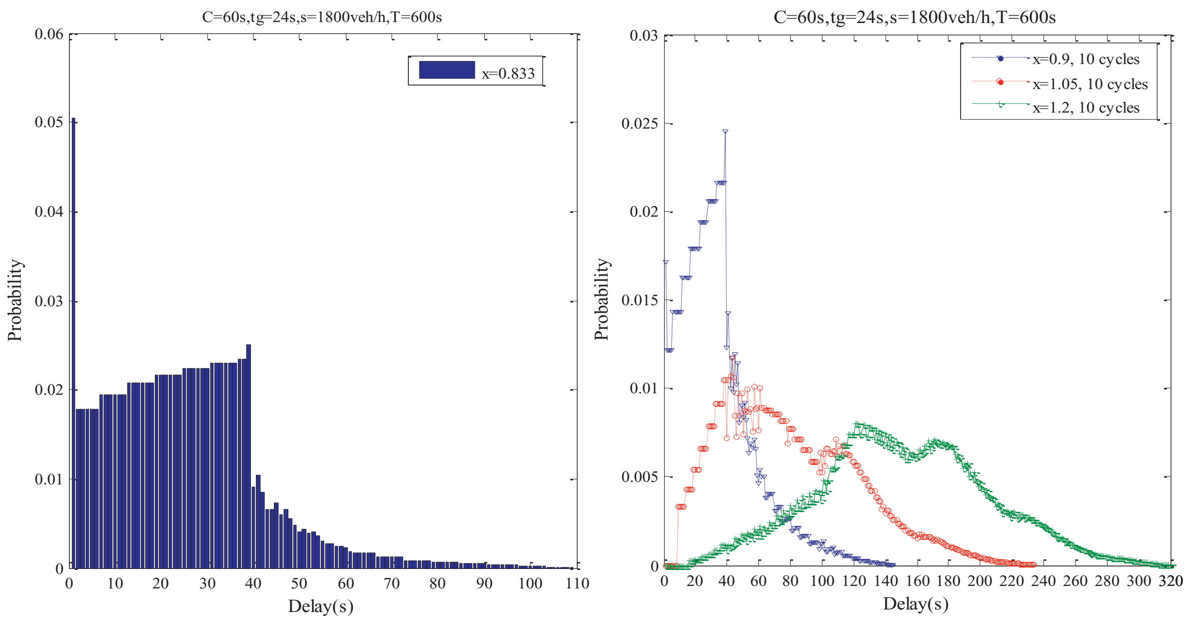


Figure 1 Delay distributions on a lane of a signalized intersection. Left the situation is given for an undersaturated signal, right for a slightly oversaturated situation.

The travel time consists of:

- delay for the signalized intersection due to the red phase,
- delay in the queue before the intersection because of oversaturation (the queue did not completely disappear at the previous green phase),
- driving time determined by free flow speed and possible interruptions on a link, e.g. crossing pedestrians, busses leaving or alighting a stop.

The first and second component of the travel time can be simulated validly by a microscopic program like VISSIM. The consistency between the analytical model and VISSIM simulations could be made by calibrating with the following benchmarks:

- free flow speed,
- overflow queue (queue length distribution at the end of green),
- green phase,
- cycle time,
- offset, and
- saturation flow rate

Zheng and van Zuylen (2011) have deduced the delay distribution formula as follows:

$$P(w|n_i) = \alpha(n_i)\delta(w) + \sum_{k=0}^{N} \beta B(w, w_{2k+1}(n_i), w_{2k+2}(n_i)) \tag{1}$$

Where $P(w|n_i)$ is the probability of delay w, given the overflow queue at the start of the red phase of n_i. The Dirac delta function $\delta(w)$ is defined by

$$\delta(w) = 0, \qquad if \quad w \neq 0$$

$$\int_{-\infty}^{+\infty} f(w)\delta(w)dw = f(0) \tag{2}$$

B(w, w_{2n-1}, w_{2n}) is a box function with the property:

$$B(w, w_{2k+1}, w_{2k+2}) = \begin{cases} 1 & w_{2k+1} < w < w_{2k+2} \\ 0 & otherwise \end{cases} \tag{3}$$

w_{2n-1}, w_{2n} are delay boundaries determined by flow, overflow queue, signal timing (e.g., red phase, cycle time and coordination of intersections in case of an urban corridor). α and β are model parameters following from the traffic state, e.g. the flow q, overflow queue n_i, the red phase t_r and cycle time C with:

$$\alpha = \max(1 - \frac{t_r + \frac{(n_i + 1)}{s}}{C(1 - \frac{q}{s})}, 0) \quad \beta = \frac{1}{C(1 - \frac{q}{s})}, \tag{4}$$

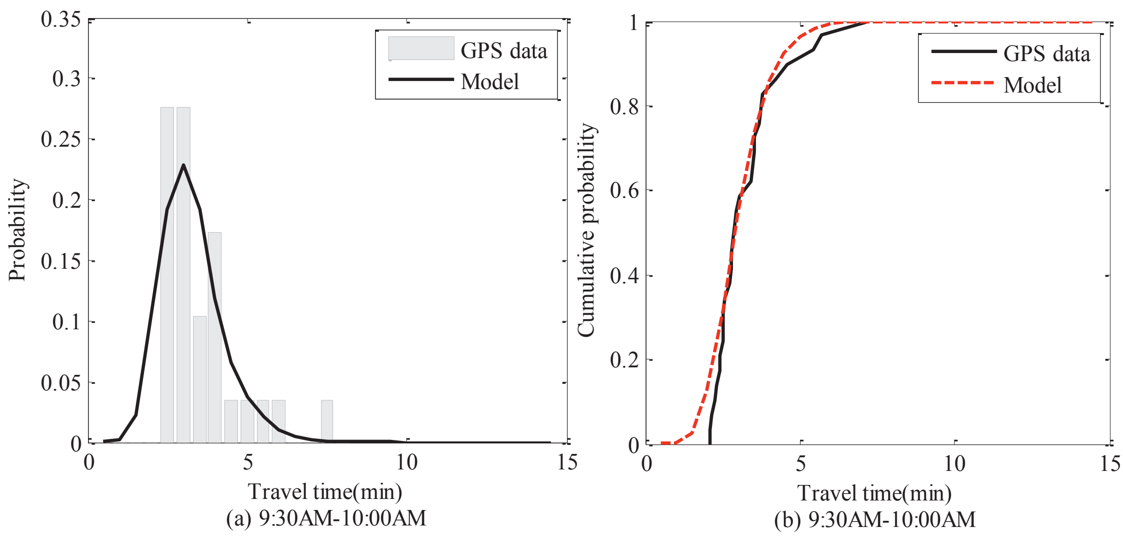


Figure 2 The travel time distribution as obtained from observed GPS data and calculated from the model (Zheng 2011)

For the details of the derivation of this formula we refer to their original publication (Zheng and van Zuylen 2011). We repeat this function (1) here to show that travel time distributions are determined by the traffic signals, the volumes, the (free flow) speed and the saturation flow rate. Since the control parameters (green phase, cycle time and offset) can directly be calibrated, the saturation flow rate has to be calibrated as described in the previous section; the crucial parameters that have to be adjusted are the free flow speed and the overflow queue distribution. The overflow queue distribution is output of VISSIM when several simulations are executed with different random seeds. The calibration of the saturation flow rates and desired speeds will be sufficient to obtain a valid simulation model in terms of the travel time distribution. Figure 2 shows how well the observed travel times match with the model.

3. Saturation flow rate

Saturation flow rates are an important characteristic for traffic flows in urban road networks. The performance of the traffic flows on signalized intersections can be determined by saturation flow rates, the flow rates and traffic control. The saturation flow rate in VISSIM is not an independent input parameter. It is determined by the car following behaviour, desired speeds, accelerations etc. Since the saturation flow rates are so important for the performance of the traffic, it is a first quantity to be reproduced by the simulation. By calibrating VISSIM with respect to saturation flow, the performance of the simulation in terms of delays and queues is taken care of at the same time, as argued in section 2.

Saturation flow rates in Chinese cities are 20 to 30% lower than the ones in The Netherland (van Zuylen et al. 2009) and furthermore the variation in saturation flow rates is higher. The later research shows that behaviour of Chinese drivers is less regular than the behaviour of Dutch drivers. A simulation program should both give valid saturation flow rates for relevant conditions and represent the variability of saturation flow rates and time headways at signalized intersections.

The statistical distribution of the saturation flows has been determined for 113 lanes on 13 intersections in downtown Changsha. Several methods can be applied to estimate saturation flow rates from traffic observations. Van Zuylen and Li (2010) compared the Regression Method (RM) as developed by Branston and van Zuylen (1978), the Highway Capacity Method (HCM) (HCM 2000) and the Product Limit Method (PLM). The HCM method basically estimates mean time headways of saturated flows and derives the saturation flow from the mean headway. It is less suited to estimate saturation flow distributions. The regression method has the advantage that it estimates also start up lags, end lags and pcu values from observed passing moments at the stop line. The PLM has the advantage that it can involve undersaturated flows, i.e. vehicles not waiting in the previous queue. For this calibration study the RM has been used.

The results of the RM analysis were used to estimate saturation flows for different kinds of lanes at the intersections. Since the lane width varied from 2.25 m to 3.60 m, the influence of lane width has also been investigated. Right turning traffic was allowed during the red phase, so that the measurement of the saturation flow on such lanes was neither needed, nor possible with the RM method. In this study, saturation flow rates were estimated for straight on and left turning lanes. There was a significant difference of saturation flows on large size intersections compared to smaller ones. Figure 3 shows the distribution of measured saturation flows. For straight on lanes the mean saturation flow rate for the first lane is 1806 pcu/h on a large intersection and 1556 pcu/h on smaller intersection. For each additional lane the saturation flow increases with 1500 and 1122 pcu/h/lane respectively. Figure 4 shows this relationship between number of lanes and saturation flow rates. The differences in saturation flow rates between small and large intersections are rather large and significant. The most plausible reason is the queue length, rather than the size of the intersections. It has been observed in another survey of saturation flows in The Netherlands that saturation flows rates are larger when vehicles had to wait in a longer queue. In the Changsha data there is also a correlation between the traffic volume and the observed saturation flow. Because it is not easy to measure exactly the maximum queue length, , the traffic volume can be used as an indicator of the traffic pressure and queue length. The multiple regression analysis of the saturation flow data gives the following relation between the saturation flow rate per lane s, the size of the intersection ($INTs$ = 1 for a large intersection with at least 4 lanes per approach, 0 otherwise, the traffic volume Q and the lane width Lw (in meters):

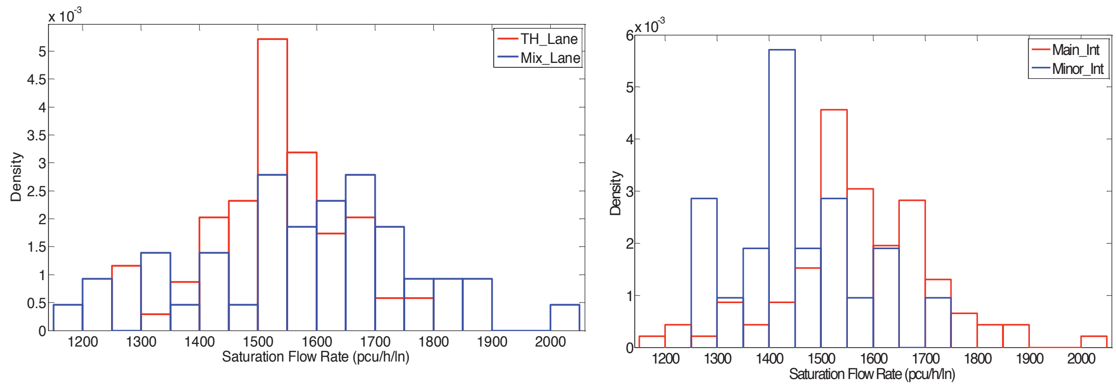
$$s = 949.184+147.6*Lw+91.5* INTs +0.262Q \tag{5}$$

The R2 of this regression is 0.37, the Root Mean Square Error is 76 pcu/h. The other statistics are given in Table 1

Table 1 Statistical charactistics of the regression coefficient in eq. (1)

coefficient	value	t-stat	p
Lw	147.6	2.7477	0.0078
$INTs$	91.5	3.6057	0.0006
Q	0.262	3.6760	0.0005

This means that the variation of saturation flows among the different lanes can be explained for 37% by these influence factors. Figure 1 also shows the distributions of saturation flow rates for lanes with a mixed use (left turning and straight on traffic) and left turning only lanes. No significant difference has been found. Left turning and mixed lanes have a saturation flow of 1668 pcu/h for one lane on a large intersection and 1621 pcu/h on smaller intersection. For each additional lane the saturation flow increases with 1474 and 1483 pcu/h/lane respectively.



(a) Through going lanes and mixed use lanes

(b) Minor and major intersections

Figure 3 Distribution of saturation flow rates

Saturation flow rates in VISSIM are not input parameters, but the results of the driver behaviour sub models. The adjustment of these parameters in the sub models should have the result that the saturation flow rates in VISSIM get the same statistical distribution as observed in reality. Apparently it is necessary to represent the saturation flow on smaller intersections differently from those on large intersections and to introduce a mechanism that changes the saturation flow rates for flows with a longer queue. Furthermore, saturation flow rates per lane should depend on the lane width and on the number of lanes for the same direction. All these requirements are not met in the standard simulation of VISSIM: the saturation flow in VISSIM does not depend on number of lanes, lane width or on the traffic flows.

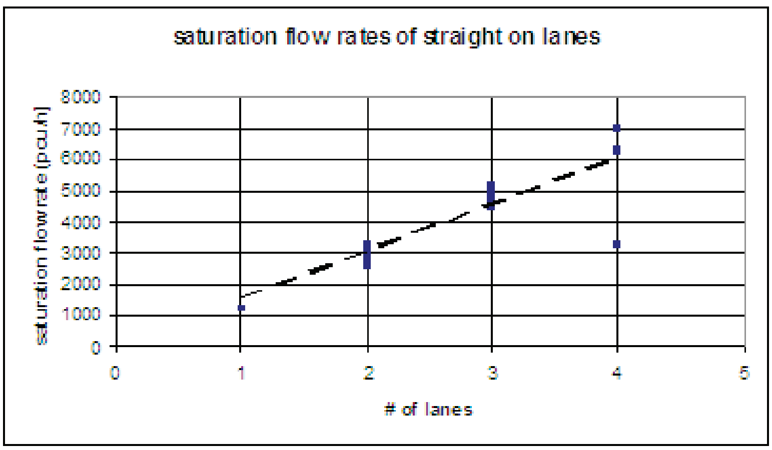


Figure 4 Saturation flow rates as function of the number of lanes on large intersections

One special aspect of driving behaviour on the studied intersection is the disobedience of the rules. The saturation flow is seriously reduced by disobedience, especially the lane changing just a few meters before the stop lines. One vehicle that changes lanes occupies two lanes at the same time. If lane changing happens, it reduces the flow rate at the stop line with 1.4 pcu for the impacted lane [Li et al. 2010].

A further characteristic of traffic control at many Chinese intersections is the lack of sufficient clearance time between the start of the red phase of one signal group and the start of green of a following conflicting signal group. At the start of the green phase some vehicles may still drive on the intersection plane. Each conflicting vehicle that is still on the intersection at the start of the green phase increases the start lag with 0.33 s [Li et al. 2010]. In the simulation this can be represented by specifying a conflict on the intersection plane or by just adding an average value of this start lag to the start of a green phase.

4. Speed and acceleration distribution

If a simulation program is used to analyze the traffic flow, queuing, delay and travel time, the calibration should at least deal with speeds and saturation flows. If micro simulations are used to assess the fuel consumption and emission of pollution the calibration should go further (Li et al. 2009, Hirschman and Fellendorf 2010): also the acceleration and deceleration behaviour in the simulation should be valid. The calibration of these parameters is described by e.g. Li (2008) and Hirschman and Fellendorf (2010). As explained in the previous section, speed distribution and saturation flows are essential calibration parameters. Since the Changsha project could dispose over GPS data of 6000 vehicles and several trips were recorded with high frequency GPS, its is obvious that we used these data to directly calibrate the desired speed, acceleration and deceleration distribution.

The desired speed distribution for traffic in Changsha was determined by selecting speeds on road sections where the normal queues for the signals do not occur. Remaining low speeds were cut off at 30 km/h. Figure 5 shows the observed cumulative speed distribution for three road sections. The 50-percentile of the desired speed is between 35 and 38 km/h, considerably lower than the default value in VISSIM.

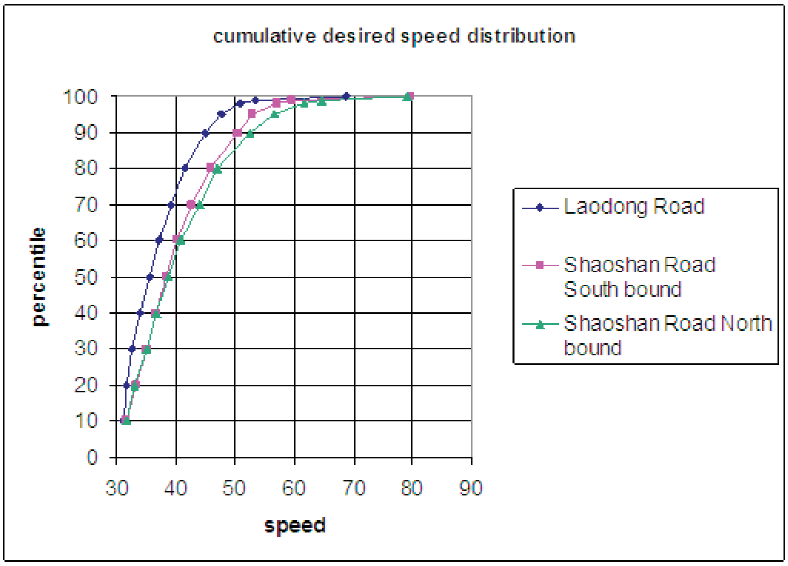


Figure 5 Cumulative distribution function for the desired speed on three road sections in Changsha

The desired acceleration can be best derived from an analysis of trajectories. Hirschman and Fellendorf (2010) measured trajectories from probe vehicles with high frequency GPS. Comparison of the acceleration behaviour of different drivers, using GPS measurements shows that each driver has another acceleration characteristic. Therefore, it would be better to determine the desired acceleration/ deceleration from several drivers. In our preliminary calibration we used the trajectories of trips by four different drivers measured with GPS. For different speed classes the 10, 50 and 99 percentiles were calculated and defined as minimum, mean and maximum acceleration and deceleration resp.

Figure 6 shows the pattern of maximum and minimum deceleration as found from the driver behaviour in Changsha. It is obvious, when these patterns are compared with the default patterns in VISSIM, that the drivers are less ‘aggressive’ in reality as in the VISSIM simulation with default parameters. This is consistent with the calibration done for an intersection in Rotterdam (The Netherlands) (Li et al. 2009).

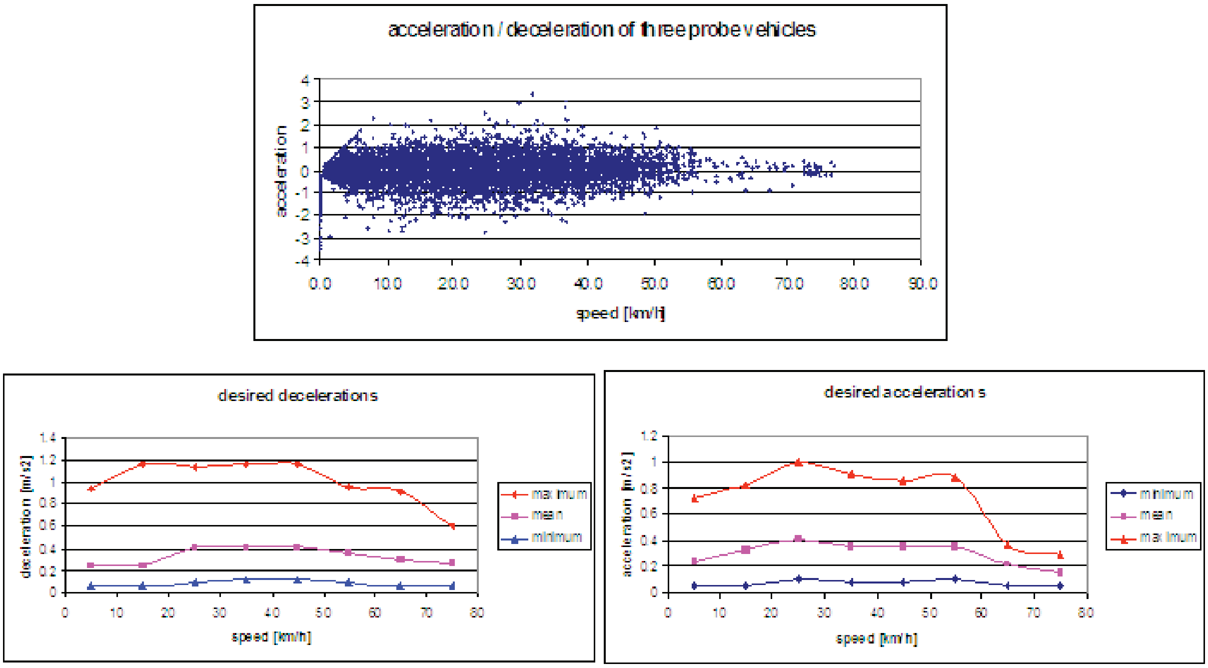


Figure 6 Desired acceleration and deceleration measured from four drivers in Changsha

5. Calibration of saturation flow rates

Not all parameters that can be chosen in VISSIM are relevant for the calibration of saturation flows. A sensitivity analysis shows that the following parameters of VISSIM have a significant influence:

- Desired speed,
- Acceleration,
- Safety distance,
- Vehicle length.

As we already calibrated the first two input parameter sets and the vehicle lengths in Changsha is not different from the ones in Europe, the only parameters left for further calibration are parameters that determine the desired distance.

In VISSIM the car following model of Wiedemann (1974) is used. This model gives the safety distance *d* between two vehicles as a function of the speed *v*:

$$d = ax + (bx\_add + bx\_mul * z)\sqrt{v} \tag{5}$$

where *ax* is the stand still distance, *bx_add* and *bx_mul* are two parameters, and *z* is a random number drawn from a normal distribution with centre at 0.5 and a standard deviation of 0.15 (these values are fixed in VISSIM).

The parameters still left over for calibration are *bx_add* and *bx_mul*. Both parameters influence the saturation flow, where it might be expected that *bx_mul* also influences the standard deviation of the saturation flow.

If the desired acceleration profiles from Figure 6 and the speed profile of Figure 5 are used, the saturation flows become very low, in the order of 950 pcu/h/lane. No significant influence of the lane width could be found. The influence of the safety distance parameters appears to be too low to bring the saturation flow rate back to the observed level.

6. Conclusion and discussion

Drivers in a Chinese city behave differently from drivers in Europe. In order to simulate traffic also for China in a valid way, one has to calibrate the simulation program. We analyzed the characteristics of traffic in Changsha, a city in the middle of China. Without claiming that driver behaviour in Changsha is representative for all Chinese cities, we conclude that we developed a calibration method that can be applied in every city where probe vehicles with GPS are driving around.

First we determined the saturation flow rates from videos and searched for patterns that describe the variation in them. We used normal taxis tracked by GPS, as well special vehicles with high frequency GPS to determine the acceleration and deceleration profiles. Speed profiles were obtained from speeds of all probe vehicles, where the speeds were measured in road sections between queuing areas. Travel times are not used for calibration, because these are determined by the desired speeds, the traffic signals and the saturation flow.

Preliminary calibration shows that the acceleration and deceleration patterns have much lower maximum end mean values than in the default parameter settings of VISSIM. Also the desired speeds are lower than the default values.

This way of calibration where traffic characteristics are determined from direct observation considerably reduces the search space. Most calibration (Park and Qi 2005) have a multi dimensional search space where a brute force search process would take too much computation time. That is not the main problem in our calibration exercise. The problem we encountered was that the observed acceleration and speed profiles give a much too low saturation flow, which could not be 'repaired' by tuning the other simulation parameters within a reasonable range.

The objective to reproduce not only the saturation flow, but also its variance makes our task complicated. Saturation flow rate of a lane appears to depend on the size of the intersection, the traffic flow on the link and the lane width. 37% of the variation of the saturation flow rate can be explained by these characteristics. In the parameter set of VISSIM only the lane width can be entered, but the effect of lane width on the saturation flow rates is not significant in the simulation. No clear mechanisms can be found to let intersection size and traffic flow influence the saturation flow. Therefore, it might be necessary to define an alternative car following model as an external function to VISSIM where such parameters can be included.

Since we also found in previous research that the observed acceleration and speeds on an intersection in The Netherlands were lower than the defaults in VISSIM and that these values produced an unrealistic saturation flow, we conclude that the discrepancy between observed characteristics of drivers and the saturation flow is not only a challenge in the calibration of VISSIM for a Chinese city.

Acknowledgements

Part of the work has been subsidized by NUFFIC and by Changsha Science and Technology Commission under contract K1001010-11. The authors recognize the support of the Sino-Netherlands ITS Training Centre and vZC.

References

Branston, D., H.J. van Zuylen (1978). The estimation of saturation flow, effective Green time and passenger car equivalents at traffic signals by multiple linear regression. *Transpn Res.*Vol 1. 12, P47-53

Dowling R., Skabardonis A., Halkias J., McHale G., Zammit G.: "Guidelines for Calibration of Microsimulation Models", *Transportation Research Record*, 1879, TRB, Washington, (2004)

Fellendorf M., Vortisch P.: Validation of the microscopic traffic flow model VISSIM in different real-world situations. *Preprint CD-ROM of 80th Annual Meeting, Transport Research Board*, Washington 2001

Hirschmann, Karin and M. Fellendorf Martin (2010) A toolbox to quantify emission reductions due to signal control, *Preprint CD-ROM of 80th Annual Meeting, Transport Research Board*, Washington 2010

Knoop, V. L., Hoogendoorn, S. P. and Van Zuylen, H. J. (2009) Processing Traffic Data collected by Remote Sensing. *Transportation Research Record* 2129, pp 55 -61

Li Jie (2008) *Preliminary analysis and calibration of the driving behavior parameters in VISSIM*, Report Delft University of Technology.

LI Jie, Henk J. van Zuylen, YuSen Chen, Ruihua LU (2010) Comparison Of Driver Behavior And Saturation Flow In China And The Netherlands, *Paper submitted to ITE journal ITS*

LI Jie, Henk J. van Zuylen, YuSen Chen, Ruihua LU (2009) Comparison of driver behavior and saturation flow in China and The Netherlands, In F Busch (Ed.), *Proceedings International Scientific Conference on Mobility and Transport* (pp. 1-15). München: Technische Universität München.

Park, B., & Qi, H. (2005). Development and Evaluation of a Procedure for the Calibration of Simulation Models. *Transportation Research Record*, No. 1934 , 208-217.

Toledo T., Koutsopoulos H.N., Davol A., Ben-Akiva E., Burghout W., Andreasson I., Johannson T., Lundin C.: "Calibration and validation of microscopic traffic simulation tools: Stockholm Case Study", *Transportation Research Record*, 1831, TRB, Washington, pp. 65-75, (2003)

Van Zuylen, Henk J., Li Jie (2009) *Measuring the saturation flow, lost time and passenger equivalent values of signalized intersection*, Research report Hunan University

Van Zuylen, H.J., Chen, Y, Li, J & Lu, R (2009). A comparison of driver behavior and saturation flow between China and the Netherlands. In s.n. (Ed.), *Proceedings 16th ITS World Congress* (pp. 1-12). Stockholm: Ertico ITS Europe.

Wiedemann, R. (1974) Simulation des Straßenverkehrsflusses, volume 8, *Schriftenreihe des IfV - Institut f ̈ur Verkehrswesen*, Universitat Karlsruhe (InGerman language),

Zheng Fangfang and Henk J.van Zuylen (2011), Estimating the delay distribution for urban trips based on sample measurements, *90th Annual Meeting Transport Research Board*, Washington January 23 – 27, 2011.

Zheng, Fangfang (2011) *Modelling urban travel times*, Thesis 2011/9 TRAIL Research School Delft.